RESEARCH PAPER

Differences Between Audiometry And Otoacoustic Emission In Tinnitus Patients

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Abstract

Background: Tinnitus is a common otological complaint that may occur with or without measurable hearing loss. Pure Tone Audiometry (PTA) is routinely used to assess patients with tinnitus; however, it may not detect early cochlear dysfunction. Otoacoustic Emission (OAE) examination provides an objective evaluation of cochlear outer hair cell function and may reveal abnormalities not identified by audiometry. This study aimed to analyze the association and differences between audiometric and otoacoustic emission findings in patients with tinnitus.

Methods: This observational cross-sectional study utilized both retrospective and prospective data from tinnitus patients attending the ENT Outpatient Clinic. Retrospective data were obtained from medical records, while additional patients were prospectively recruited due to incomplete data. Non-probability sampling methods were applied. Data on demographic characteristics, PTA, and OAE findings were analyzed using the Chi-square test, followed by Cramer's V to assess the strength of association.

Results: A total of 50 tinnitus patients were included. Audiometric findings ranged from normal hearing to varying degrees of hearing loss. Some patients with normal audiometric thresholds demonstrated abnormal OAE results. A statistically significant relationship between PTA and OAE findings was observed ($p < 0.05$), with a strong association.

Conclusion: PTA and OAE findings in tinnitus patients show a significant association, with observable discrepancies in certain cases. OAE may detect early cochlear changes not identified by audiometry alone, supporting the complementary use of both examinations in tinnitus evaluation.

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Introduction

Tinnitus is the hearing of sound in the head without the presence of an external source. Tinnitus is often defined as a high-pitched ringing or buzzing that is usually only audible to the affected individual. Most tinnitus is subjective, which is inaudible to the examiner. However, an examiner may be able to hear objective tinnitus in cases arising from aneurysms. Tinnitus majorly presents in the form of a ringing sound, while for others, it may be thumping, whooshing, roaring, clicking, hissing, buzzing, or shrieking. The sound may be soft or loud, high-pitched or low-pitched. The sound might be heard from either one ear or both, from inside the head, or from a distance. It may also be constant or intermittent, steady or pulsating. People with tinnitus may also experience heart palpitations, an increased heartbeat, and lightheadedness. Tinnitus is a common problem for millions of individuals, affecting about 10% to 20% of people (approximately 1 out of 10), and is especially common in older adults, with peak incidence between 60 and 69 years of age. Almost everyone has experienced short-term tinnitus after being exposed to extremely loud noise, such as attending a loud concert. Tinnitus is most commonly associated with hearing loss, which triggers neuroplastic changes in central auditory pathways, but hearing loss in tinnitus patients does not necessarily rule out cochlear damage. To assess cochlear activity in tinnitus, distortion product otoacoustic emissions (DPOAEs) and audiograms can be measured.

Tinnitus is commonly associated with hearing loss, noise exposure, aging, ototoxicity, and dysfunction within the cochlea or central auditory pathways (Carl, 2023).

Audiological assessment plays an important role in identifying the underlying pathology in patients with tinnitus and in guiding management strategies. Pure-tone audiometry (PTA) is considered the gold standard for evaluating hearing sensitivity. It is a subjective test that determines hearing thresholds across frequencies and helps classify hearing loss as conductive, sensorineural, or mixed. However, some tinnitus patients may have normal hearing thresholds on conventional audiometry despite experiencing significant auditory symptoms, a condition often referred to as "hidden hearing loss" (Banga, 2023).

In contrast, otoacoustic emissions (OAEs) are objective, noninvasive measurements of sounds generated by the outer hair cells of the cochlea either spontaneously or in response to acoustic stimulation. OAEs, including transient-evoked otoacoustic emissions (TEOAEs) and distortion-product otoacoustic emissions (DPOAEs), are useful in assessing cochlear outer hair cell function and may detect subtle cochlear damage before it becomes evident on pure-tone audiometry (Engdahl, 2013).

Several studies have demonstrated discrepancies between audiometric thresholds and OAE findings in patients with tinnitus. Some individuals with tinnitus and normal PTA hearing show reduced or absent OAEs, suggesting early outer hair cell dysfunction or cochlear

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damage not detectable by conventional hearing tests. Conversely, audiometric abnormalities may coexist with reduced OAEs in patients with more advanced cochlear pathology. Understanding these differences may provide insight into the pathophysiology of tinnitus and improve early diagnosis and treatment planning (Badri,2011).

Material Methods

This study was an analytical observational cross-sectional study. Retrospective data were initially obtained from patients' medical records. However, due to incomplete data in some medical records, additional data were obtained by prospectively recruiting new patients to fulfill the required sample size. The population of this study comprises patients with tinnitus from the medical records of the ENT-HNS Audiology Department's outpatient clinic at Dr. Soetomo Hospital, Surabaya. The subjects in this study were patients with tinnitus who met the following Inclusion criteria and exclusion criteria. Inclusion criteria: Patients diagnosed with tinnitus, Tinnitus patients with complete Pure Tone Audiometry (PTA) and Otoacoustic Emission (OAE) examination data available in the medical records at Dr. Soetomo Hospital, Surabaya. Exclusion criteria: Patients with a perforated tympanic membrane, Patients with otitis media or other middle ear infections that could affect the accuracy of audiological assessments.

This study employed a non-probability sampling technique. For the retrospective component, total sampling was applied. Medical records of patients diagnosed with tinnitus from January 2022 to December 2025 were reviewed. Patients who met the inclusion and exclusion criteria and had complete PTA and OAE data were included in the study. For the prospective component, consecutive sampling was conducted. Patients presenting to the ENT Audiology outpatient clinic with tinnitus during the study period who met the inclusion criteria were recruited consecutively. PTA and OAE examinations were performed on the same day of the clinic visit to ensure consistency of data collection.

The timing of PTA and OAE examinations varied between the retrospective and prospective components of the study. For retrospectively collected data, PTA and OAE tests were not always performed simultaneously, as they were conducted based on routine clinical practice and patient follow-up schedules. In contrast, for the prospective component, both examinations were performed on the same day to ensure consistency. Despite this variation, the data were considered valid for analysis, as both PTA and OAE assess relatively stable aspects of auditory function in the absence of acute pathology. In addition, patients with middle ear conditions that could significantly affect test results were excluded. Therefore, the data were deemed sufficiently reliable for evaluating the relationship between PTA and OAE findings.

This study was conducted after ethical approval was obtained from the Ethics Committee of Dr. Soetomo Hospital (No. 1471/KEPK/XI/2025).

Results

A total of 50 tinnitus patients who met the inclusion and exclusion criteria and had complete Pure Tone Audiometry (PTA) and Otoacoustic Emission (OAE) data were included in this study. The data were collected from both retrospective medical records and prospectively recruited patients from the ENT-HNS Audiology Outpatient Clinic between January 2022 and December 2025.

Table 1. Gender Distribution of Study Subjects

Variable	n	percentage (%)
Gender		
Male	23	46.0
Female	27	54.0
Age Group (years)		
≤20 years old	5	10.0
21-40 years old	13	26.0
41-60 years old	22	44.0
>60 years old	10	20.0
Age		
Early Adolescence	3	6%
Late Adolescence	3	6%
Early Adulthood	11	22%
Late Adulthood	10	20%
Early Elderly	10	20%
Late Elderly	7	14%
Manula	6	12%

Of the 50 subjects, 23 (46%) were male and 27 (54%) were female, indicating a slightly higher proportion of female tinnitus patients. The age of subjects ranged from 15 to 75 years. Most patients were adults and elderly, suggesting an increased prevalence of tinnitus with advancing age. Based on the table of respondent characteristics, of the 50 respondents, the majority were in the early adulthood age group, totaling 11 (22%). This was followed by the late-adulthood and early-elderly groups, each consisting of 10 respondents (20%). Respondents in the late elderly group totaled 7 respondents (14%), followed by the very old group with 6 respondents (12%). Meanwhile, the early and late adolescence groups had the fewest respondents, with 3 respondents (6%) each.

Table 2. Hearing Level Distribution Based on PTA and OAE in Tinnitus Patients

Variable	n	percentage (%)
Hearing Level		
Normal	16	32 %
Mild hearing loss	14	28 %
Moderately hearing loss	11	22
Moderately severe hearing loss	8	16 %
Severe hearing loss	1	2 %
OAE Result		
PASS	9	18 %
REFER	41	82 %
PTA		
Normal	16	32%
Abnormal	34	68%

Based on the frequency distribution table of OAE examination results, 41 respondents (82%) had REFER results. Meanwhile, respondents with PASS results numbered 9 (18%). Based on the frequency distribution table of PTA examination results among respondents, 34 respondents (68%) were in the abnormal category. Meanwhile, respondents with normal results numbered 16 (32%).

Table 3. results of the analysis to determine the relationship between PTA and OAE.

	OAE				Total		P-Value
PTA	**PASS**	**(%)**	**REFER**	**(%)**			
Normal	9	18	5	10	14	28	0.001
Abnormal	0	0	36	72	36	72	
Total	**9**	**18**	**41**	**82**	**50**	**100**	

Based on the table showing the relationship between PTA and OAE, 16 respondents had normal PTA results; the majority had OAE PASS results (9, 18%), while 5 had OAE REFER results (10%). Among the 36 respondents with abnormal PTA results, all had OAE REFER results (72%), and none had OAE PASS results. The statistical analysis showed a p-value of < 0.001 ($p < 0.05$), indicating a significant relationship between PTA and OAE examination results.

Table 4. Cramer's V Test

Cramer's V Value	Strength	Relationship Between PTA and OAE	
		P Value	Coefficient
0.00 – 0.10	Very Weak		
0.10 – 0.20	Weak		
0.20 – 0.40	Moderate		
0.40 – 0.60	Strong	0.751	0.000
0.60 – 0.80	Very Strong		
0.80 - 1	Perfect/Extremely Strong		

Based on the results of the analysis examining the relationship between PTA and OAE, a p-value of 0.001 ($p < 0.05$) was obtained. This indicates that there is a statistically significant relationship between PTA and OAE examination results among the study respondents. Furthermore, the Cramer's V coefficient was 0.751, indicating that the strength of the relationship between PTA and OAE results falls into the "very strong" category. This suggests that changes or differences in PTA results are very strongly associated with the outcomes of OAE examinations. Therefore, it can be concluded that there is a significant and very strong relationship between PTA and OAE results, where respondents with abnormal PTA results tend to have OAE "REFER" results, while respondents with normal PTA results are more likely to have OAE "PASS" results.

Discussions

The age distribution in this study ranged from adolescence to elderly adulthood, with the majority of patients belonging to the 41–60 year age group. This finding is consistent with existing literature reporting an increased prevalence of tinnitus with advancing age (WHO, n.d.). Age-related changes in the auditory system, particularly degeneration of cochlear hair cells and neural elements, are believed to contribute significantly to tinnitus development (Haider et al., 2018).

Presbycusis is characterized by progressive deterioration of cochlear structures, including outer hair cells, inner hair cells, and spiral ganglion neurons. Even before audiometric thresholds become elevated, subclinical cochlear damage may occur (Kara et al., 2020). This phenomenon may explain why some middle-aged

patients in this study presented with tinnitus despite having normal PTA results. Previous studies have suggested that age-related synaptopathy and subtle cochlear damage may be responsible for tinnitus perception prior to overt hearing loss (Jeong et al., 2022).

A slightly higher proportion of female patients was observed in this study. While some epidemiological studies report a higher prevalence of tinnitus among males due to greater occupational noise exposure, other studies have demonstrated no significant gender difference or a female predominance (Sztuka et al., 2009). Hormonal influences, stress perception, and healthcare-seeking behavior may contribute to these inconsistencies.

Most patients in this study did not report accompanying vertigo, suggesting that the majority of tinnitus cases were not associated with overt vestibular pathology. This finding is consistent with subjective tinnitus of cochlear or central auditory origin rather than peripheral vestibular disorders such as Ménière's disease.

Pure Tone Audiometry revealed a wide range of hearing thresholds among tinnitus patients, from normal hearing to severe hearing loss. Approximately one-third of the subjects demonstrated normal hearing thresholds, while the remaining patients exhibited varying degrees of sensorineural hearing loss. Similar findings have been reported in previous studies, where tinnitus was frequently observed in individuals with mild to moderate hearing impairment (Dong-Kee Kim et al., 2011).

The presence of tinnitus in patients with normal audiometric thresholds supports earlier observations that tinnitus does not always correlate with measurable hearing loss on conventional audiometry (Sztuka et al., 2009). Standard PTA primarily assesses hearing sensitivity between 250 Hz and 8 kHz and may fail to detect subtle cochlear damage, particularly at extended high frequencies or at the synaptic level (Salmon et al., 2023).

In patients with hearing loss, tinnitus is often explained by reduced auditory input leading to maladaptive neuroplastic changes within the central auditory pathways (Haider et al., 2018). Deafferentation may result in increased spontaneous neural firing and altered cortical organization, contributing to tinnitus perception. Therefore, the audiometric findings in this study are in accordance with established models of tinnitus pathophysiology.

Importantly, abnormal OAE findings were also observed in patients with normal audiometric thresholds. This suggests that OAE testing is more sensitive than PTA in detecting early or subclinical cochlear dysfunction. Outer hair cells may be damaged by noise exposure, aging, or metabolic stress before inner hair cells and neural structures are sufficiently affected to elevate hearing thresholds (Alshabory, Gabr and Kotait, 2021).

These findings are consistent with previous studies demonstrating reduced OAE amplitudes or absent OAEs in tinnitus patients with normal hearing (Sztuka et al., 2009; Kara et al., 2020). Collectively, these results support the hypothesis that outer hair cell dysfunction represents an important peripheral mechanism in tinnitus generation.

The comparison between PTA and OAE findings revealed clear differences between these two diagnostic modalities. While audiometry evaluates behavioral hearing thresholds and depends on patient responses, OAE provides an objective assessment of cochlear outer hair cell integrity (Interacoustics, 2023). In this study, several patients with normal PTA results demonstrated abnormal OAE findings. This discrepancy underscores the limitation of audiometry in detecting early cochlear damage and supports the concept of "hidden hearing loss" or cochlear synaptopathy (Kara et al., 2020). Conversely, patients with moderate to severe hearing loss consistently showed abnormal OAE results, reflecting more extensive cochlear damage.

The Chi-square test demonstrated a statistically significant association between PTA hearing levels and OAE results ($p < 0.05$). The strength of this association, assessed using Cramer's V, indicated a very strong relationship between the two variables. This finding suggests that worsening audiometric thresholds are strongly associated with an increased likelihood of abnormal otoacoustic emission results. However, despite this strong association, Pure Tone Audiometry and Otoacoustic Emission evaluate different aspects of auditory function. PTA reflects behavioral hearing thresholds, whereas OAE provides an objective assessment of cochlear outer hair cell function. Therefore, discrepancies between the two tests may still occur, particularly in early or subclinical cochlear dysfunction. Similar associations between audiometric hearing loss and reduced OAE responses have been reported in previous studies, supporting the relationship between cochlear outer hair cell dysfunction and elevated hearing thresholds (Abdala and Visser-Dumont, 2001; Alshabory, Gabr and Kotait, 2021).

However, statistical significance does not imply equivalence between the two assessment methods. The presence of abnormal OAE findings in patients with normal PTA thresholds highlights the limitation of audiometry in detecting early cochlear pathology. This phenomenon has been described in the context of hidden hearing loss and cochlear synaptopathy, where peripheral auditory damage exists despite normal behavioral thresholds (Kara et al., 2020; Jeong et al., 2022).

The findings of this study have several important clinical implications. First, tinnitus patients with normal audiograms should not be assumed to have normal cochlear function. Abnormal OAE findings in these patients suggest early outer hair cell dysfunction, which may precede detectable hearing loss on conventional audiometry (Sztuka et al., 2009; Kara et al., 2020). Second, incorporating OAE testing into the routine assessment of tinnitus patients may improve diagnostic accuracy and enhance clinical decision-making. Objective identification of cochlear dysfunction may assist clinicians in counseling patients regarding the possible origin of their tinnitus and the importance of preventive measures, such as noise avoidance and

hearing conservation strategies (Interacoustics, 2023). Finally, early detection of cochlear abnormalities through OAE may allow timely intervention and monitoring, potentially reducing the progression of auditory dysfunction. These findings support the role of OAE as a valuable adjunct to audiometry rather than a replacement, particularly in patients with normal or near-normal hearing thresholds.

Conclusions

There are observable differences between Pure Tone Audiometry and Otoacoustic Emission findings in tinnitus patients. While audiometry may show normal hearing thresholds in some patients, Otoacoustic Emission testing can reveal underlying cochlear dysfunction. These findings indicate that otoacoustic emission examination may detect early cochlear changes not identified by audiometry alone. There is a statistically significant and very strong association between Pure Tone Audiometry (PTA) and Otoacoustic Emission (OAE) findings in patients with tinnitus. However, discrepancies were observed in some cases, where patients with normal PTA results showed abnormal OAE findings. This suggests that OAE may detect early cochlear changes not identified by audiometry alone. Therefore, the combined use of PTA and OAE is important for a more comprehensive evaluation of tinnitus patients.

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